Production of Hydrogen Energy in the Far East

(Construction of Hydrogen-Producing Plant in the Sakhalin Region)

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Hydrogen is one of the most common chemical elements on Earth. It is found in considerable amounts in water and in fossil fuels such as coal, oil, and natural gas. Both Russian and foreign experts have predicted that commercially profitable supplies of essential fossil fuels such as oil and natural gas will deplete rapidly in the next 20~30 years. This could lead to a collapse of the modern gas and residual energy system as well as the transportation system.

Therefore, the global science community is in a constant search for alternative fuels. The most promising source of energy is believed to be hydrogen.

The problem of resource depletion is particularly urgent from the viewpoint of transportation systems. Rail transport mostly uses electricity and can use steam power in areas without electrified railways. In contrast, no alternatives yet exist for automotive and air transport, although the use of hydrogen as an alternative is being considered seriously. Marine transport mostly uses fossil fuels as well. Although marine transport could potentially switch to nuclear or coal power, with wind as an additional power source, realizing such a switch would likely be prohibitively expensive.

The substitution of natural gas as a power plant fuel is very important, especially in countries where the population is accustomed to clean air in the cities and ecological issues have gained an important status (e.g., USA, EU, Japan). Hydrogen compounded with oxygen produces a great amount of energy. The result of this reaction is pure water, making hydrogen the most eco-friendly fuel, even more so than natural gas.

However, pure hydrogen does not occur naturally, and a considerable amount of electricity is required to produce it from water by electrolysis. In fact, hydrogen derived by this method becomes an artificially created energy source, unlike fossil fuels. Among secondary energies, electricity is superior in many aspects; however, unlike fossil fuels, it cannot be transported over the sea.

If hydrogen can be inexpensively obtained from water by electrolysis and also be liquefied inexpensively, it would be much more preferable than electricity that is transported over long distances using expensive power lines.

In addition, large-scale implementation of hydrogen as an energy source for industry, transport, and housing and community services would greatly reduce carbon dioxide (CO_2) emissions into the atmosphere. It is well known that under Prime Minister Hatoyama, Japan pledged to reduce CO_2 emissions into the atmosphere by 25%. This requires the development and application of new technologies, because Japan has already applied all existing technologies to reduce CO_2 emissions.

In Japan, the large-scale implementation of hydrogen as an energy source for industry, energy, and transport is considered to be the most promising solution to reduce the country's consumption of fossil fuels. At some point in the future, hydrogen could potentially replace such fuels completely. This would considerably reduce CO_2 emissions and reduce the country's dependence on oil and gas imported from the Middle East.

Presently, hydrogen is already being used in several fields:

- Electric power industry: hydrogen is used in steam turbines and in hydrogen-consuming turbines
- Steel production: hydrogen is insufflated into the cold-rolling mill and is used for iron ore granulation
- Automotive industry: hydrogen is used to power fuel cell vehicles and is used on-board in vehicles with internal combustion engines (e.g., diesel engines)
- Municipal gas: hydrogen is added to adjust the combustion-heat within legally allowed limits
- Space industry

However, in Japan, hydrogen remains too expensive for most applications: 1 m^3 of hydrogen costs roughly 100 cents, whereas 1 m^3 of liquefied natural gas (LNG) costs roughly 40 cents.

To increase the competitiveness of hydrogen, Japanese companies began studying the possibility of approved large-scale and inexpensive hydrogen production using renewable energy sources overseas, for export of the finished product to Japan.

A ready and large source of renewable energy is the wind that blows from the polar regions. For example, strong winds blow from the North Pole through the Bering Sea to the North Pacific; as a result, the Aleutian Islands have an annual average wind speed of approximately 10 m/s. Equally strong winds blow from the South Pole.

Consequently, three of the most suitable regions for the production of hydrogen using wind power were Patagonia (Argentina), the Aleutian Islands (Alaska, USA), and the Sakhalin region (Russia). A project has been underway in Patagonia with assistance from the Japanese government since the last four years; however, the region's 12,200 km distance from Japan lessens its appeal. Thus, Sakhalin Island has attracted increasing attention because of its proximity to Japan.

To reduce costs and simplify transportation, Japanese scientists have recommended the liquefaction of hydrogen by compounding with toluene, i.e., catalytic hydrogenation of toluene. A liquid organic chemical hydride, methylcyclohexane, is formed as a result. This product, like gasoline, has a moderate boiling point (101.1°C), volatility, and toxicity. The hydrogen content is approximately 6.16%.

Low-temperature regasification of hydrogen, i.e., catalytic dehydrogenation of toluene, is a particularly important development that has been reported by Japanese scientists led by Professor Yasukazu Saito. This process allows the extraction of hydrogen from methylcyclohexane, using waste heat from industrial plants and thermal power systems. Compared to the cryogenic cooling method, the chemical method of hydrogen liquefaction into methylcyclohexaneconsiderably reduces costs and simplifies transportation and storage of the finished product.

At the same time, it is essential to remember that the purpose is to deliver hydrogen to the consumer as a manmade source of energy, and methylcyclohexane is just a carrier.

The Sakhalin area is the closest region to Japan with the necessary wind resources, which is why a number of Japanese companies are actively promoting the construction of a hydrogen-producing plant in this region. Their interest is represented by International Wind Hydrogen Inc. (IWHI), which was specifically founded in Tokyo on May 15, 2009, for this project. The Russian autonomous non-commercial organization, The Far Eastern Center for Strategic Research on Fuel and Energy Complex (FEC SR FEC), based in Vladivostok, is actively cooperating on this project.

IWHI is situated at Yamada Line Bldg. III 7F, 2-11-10, Iidabashi, Chiyoda-ku, Tokyo 102-0072, Japan. The president of the company is Senichi Shamoto, who has worked in the area of LNG supply for 40 years and is considered one of the founder of the field.

One of the founders and managers of the company is Dr. Yasukazu Saito, Director of the New Energy Institute of Tokyo and an honored professor. He developed the inexpensive method for hydrogen extraction from methylcyclohexane.

Dr. Saito has for many years been the chairman of the Academic Council of Japan for Hydrogen Energy and Catalysts.

Another founder and director of the company is Sunichi Shimizu, the President of the Communication System Problems Research, Utilities and Energetics Institute. Susumu Yoshida, well known in Japanese and Russian industrial circles, and Chairman of the ERINA institute, is also involved in the project.

Originally, the Japanese planned to build a plant on Urup or on the eastern coast of the Terpeniya peninsula, because of the availability of wind resources in that area. However, analysis of the research on possible plant locations, conducted by FEC SR FEC, revealed the excellent prospects of the western coast of the Krylonsky peninsula, up to the Nevelsk port.

After examination of the sites in October 2010, members of IWHI confirmed the preliminary results.

The schematic circuit of the project is to build a wind power plant of up to 50 GW with approximately 10,000 wind generators of 5 MW each in the Sakhalin region. With the inexpensive energy thus produced, water electrolysis will produce up to 3.8 million tons of hydrogen per year. The produced hydrogen will be liquefied by binding it with toluene, thus obtaining a liquid chemical product, methylcyclohexane. Up to 62 million tons of methylcyclohexane per year are planned to be produced, which will be shipped through a specially designed bulk terminal into tankers with a deadweight of up to 100,000 tons.

The initiators of the project would welcome the purchase of some of the product by Russian consumers, and possibly by consumers from other countries. They believe that this would considerably accelerate the payment of investments.

As mentioned above, methylcyclohexane created using toluene is mildly toxic, moderately flammable, and stable in liquid form; in addition, it does not require cryogenic cooling and it may be transported by conventional chemical tankers or pipelines.

Consumers will be able to store methylcyclohexane in conventional chemical tanks and easily extract hydrogen when needed, thus making it possible to maintain a strategic hydrogen stock. The toluene remaining after extraction will be returned in tankers to the plant for repeated use.

Production is planned to start between 2015 and 2020 and continue for 20 years. Excluding the effect of lowering the prime cost by enlarging the scale of production, 1 m^3 of hydrogen after regasification at the consumer's site will cost roughly 30 cents.

Basic research for the project is conducted by IWHI and FEC SR FEC. Presumably, feasibility studies will be conducted by IWHI and FEC SR FEC in collaboration with Nomura Research Institute, Mitsubishi Research Institute, and the American companies Bechtel, SRI International, and others. It is expected that the Japanese companies JGC Corporation, Nikki, Chiyoda, and others will be involved in the general design and construction.

It is expected that the wind power station will be constructed using technology and equipment from General Electric (USA); Mitsubishi Heavy Industries, Ltd.; The Japan Steel Works, Ltd.; Hitachi, Ltd.; Fuji Heavy Industries, Ltd. (Japan); and others. Water electrolysis technologies will be implemented by the Canadian company Hydro-Quebec and the American company Air Products and Chemicals Inc. (APCI). Liquefaction of hydrogen will be carried out using technology from APCI and others. Berthing facilities and tanks will be built by Nippon Steel and Shimizu Construction (Japan). Regasification of hydrogen in Japan will be implemented using Dr. Saito's method.

It is expected that the plant will be operated through a collaboration between Japan, Russia, and the USA.

To solve various technical problems that may occur along different stages of the project's technological chain, from wind power stations to regasification of hydrogen on the consumer's site, there is a protocol of understanding between Dr. Yasukazu Saito and Professor V.I. Sergienko, chairman of the Far Eastern Branch of the Russian Academy of Science (FEB RAS). Currently, a Japanese-Russian science and technical team has been formed and based on this protocol.

The founders of the project set its price at approximately 10 billion USD, including 3 billion USD for pre-project research and 100 million USD for preparation of the working sketches.

At the invitation of the Sakhalin region's government, a delegation consisting of S. Yoshida, S. Shamoto, and Y. Saito visited Sakhalin on October 16 – 20, 2010. They negotiated with the first deputy chairman of the region's government, S.G. Sheredekin, spokesmen of the ministries and departments of the region, and FEC SR FEC officials.

As a result of said negotiations, a protocol has been signed, stating that feasibility studies will be finished between 2010 and 2012. Based on the feasibility study, a general plan for the realization of the project will be developed, for which the parties will consider creating a joint organization.

At a November 2010 meeting in Tokyo, IWHI and FEC SR FEC officials approved a joint plan of actions for 2011 and direction for further work, as progress of the abovementioned protocol agreements.

It is agreed that by the end of August 2011, the pre-feasibility study should be finished. After its assessment, work on the detailed feasibility study will be started in October 2011.

Within the pre-feasibility study, during the period from the end of May until the end of June 2011, a number of expert groups from Japan will travel to the Sakhalin region to examine the Nevelsk-Gornozavodsk-Shebunino area and clarify the possibilities of effectively using local infrastructure for the needs of the project, including ports, roads, power lines, water sources, and possible construction sites.

An automated anemometer will be set up at the proposed construction site, allowing the power and direction of the wind to be monitored in real time through the internet. IWHI also intends to assess possible sites suitable for construction south of Shebunino for preparation of future extension of the project. All the abovementioned tasks in the Sakhalin region will be implemented by FEC SR FEC and FEB RAS with the Sakhalin government's agreement.

As the first stage for the detailed feasibility study development, accounting for the results of the pre-feasibility study, a pilot plant will be designed and built on the Krylonsky peninsula.

As part of this enterprise, a wind power plant, consisting of 10 wind generators of 1 MW each, will be constructed at the potential wind energy complex site.

This concept is based on the Eurous Energy company's experience in the use of 57 wind generators of 1 MW each, manufactured by Mitsubishi Heavy Ind., at the Soya wind power station (Hokkaido Island), situated 40 km from the Krylonsky peninsula. The wind generator utilization coefficient at the Soya power station is approximately 90%.

During the construction and operation of the pilot power station, the following issues will be studied:

- Prime cost of transferring the energy from the wind energy complex to the organic hydride producing plant.
- Logistics of transporting the wind generators to the construction site.
- Impact of the 10 wind generators on the environment and local population.

Included as part of the pilot enterprise is the organic hydride producing plant, with equipment for water hydrolysis directly connected to the organic hydride producing equipment, storage tanks, and shipping terminal.

The capacity of the plant will be programmed for electricity, which will be produced by 10 wind generators of 1 MW each.

The operation of the pilot enterprise will allow not only practical work on the technical aspects of production and chemical liquefaction of hydrogen, its transport, acceptance in Japanese ports, storage, regasification, and utilization, but also precise assessment of the prospect of creating a mass market of hydrogen in Japan and associated expenses.

Accounting for the received data, the next stage of the feasibility study is to expand the capacity of the pilot enterprise by ten times; the capacity of the power station will be increased to 100 MW with the subsequent expansion of the other subdivisions' power.

This step-by-step approach will avoid rushing forward and will allow the scientific, technical, and economic issues to be solved in time while achieving the best return on the investment.

Financing of the project is expected to be obtained from private investment with the Japanese Bank of International Cooperation (JBIC) and the Japanese New Energy Development Organization (NEDO).

According to an FEB RAS expert assessment, this project is very profitable for the Russian Federation for the following reasons:

- Russia will receive access to the most advanced technologies in electricity generation, as well as receipt and liquefaction of hydrogen.
- Hydrogen energy may devalue the fossil fuel resources of Russia; therefore, large-scale production of hydrogen in its territory allows Russia to, over time, successfully master new energy resources in order to protect Russian interests.
- Large-scale production of inexpensive hydrogen in the Far East will satisfy the needs of the space launching site in the Amur area.
- In the Sakhalin region, a new energy center will be created based on renewable resources with a capacity of up to 50 GW; currently, the capacity of all power stations in the Far East is approximately 14 GW.
- Further development of Russian and Japanese economic cooperation will improve the relations of our country with one of the world's economic and technical leaders.
- Large investments will be directed into the economy of the Sakhalin region.

Thus, the project not only has considerable economic, scientific, and technical value but will also serve to foster peace and goodwill in Northeastern Asia. It is therefore open to all interested participants.